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MILLING METHODS AT THE HURLEY PLANT OF THE NEVADA CONSOLIDATED COPPER CO., HURLEY, NEW MEXICO

BY

FRED HODGES

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MILLING METHODS AT THE HURLEY PLANT OF THE NEVADA CONSOLIDATED COPPER CO., HURLEY, N. MEX.[1]

By Fred Hodges[2]

INTRODUCTION

This paper describing the concentrator practice of the Hurley Plant of the Nevada Consolidated Copper Co. at Hurley, N. Mex., is one of a series of papers on milling methods and costs being prepared by the United States Bureau of Mines.

The Hurley concentrator has a normal daily capacity of 13,500 tons of ore, and for the first four months of 1930 the heads of the concentrator averaged 1.32 per cent of copper and 3.14 per cent of iron. The recovery for this period was 83.98 per cent and the concentrates produced averaged 27.54 per cent of copper.

Location of Mine and Concentrator

The mine and concentrator are located at Santa Rita and Hurley, respectively, in Grant County, N. Mex. Mining is done in open pits with power shovels.

Water

Water is obtained from wells located in the vicinity of the concentrator, and during the rainy season run-off water is impounded and made available for milling purposes.

Power

Power for mining and milling is obtained from the company's steam plant located at the concentrator. The power plant consists of three Allis-Chalmers turbo-generators, one 7,500-kilowatt, one 6,000-kilowatt, and one 2,000-kilowatt. Three Nordberg reciprocating units, each of 1,250-kilowatt capacity, are used in emergency.

Steam at 188 pounds pressure is furnished by five boiler units each equipped with two Heine water tube boilers and one 11,000 pounds per hour "Aero" type coal pulverizer. The boilers are operating under approximately 1 inch of induced draft furnished by two 16-foot Sturtevant fans. Slack coal is obtained from the Gallup coal fields in northwestern New Mexico.

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6394."

[2] - One of the consulting engineers, U. S. Bureau of Mines, and concentrator superintendent, Hurley Plant, Nevada Consolidated Copper Co.

Power is generated at both 6,600 and 480 volts and is stepped up to 24,000 volts for transmission to the mine at Santa Rita and to the pumping stations near Hurley. Power for milling purposes is transmitted at 480 volts.

ORE TREATED

The ore as it comes from the mine varies greatly in physical properties, as that mined from the lower benches being somewhat softer than the ore from the upper benches. The copper mineral is principally chalcocite, although this in places is accompanied by azurite, malachite, chrysocolla, and cuprite.

The highly metamorphosed quartz diorite porphyry and sedimentary rocks, in which the ore minerals are found, are greatly fractured. The chalcocite occurs along these fractures in small stringers and veinlets, and also in part as small disseminated grains scattered throughout the rocks. It replaces pyrite, but in many instances this replacement has not been complete, so that the chalcocite forms a shell around a remnant of pyrite.

The gangue minerals, quartz, pyrite, sericite, and halloysite are associated with the chalcocite. The copper minerals of the ore, in their associations and proportions to the gangue minerals, vary in different parts of the mine, so that in these respects there is little uniformity in the ore as received at the concentrator.

Small amounts of gold and silver occur in the ore. The concentrates produced after milling contain approximately 0.040 ounce of gold and 0.55 ounce of silver per ton.

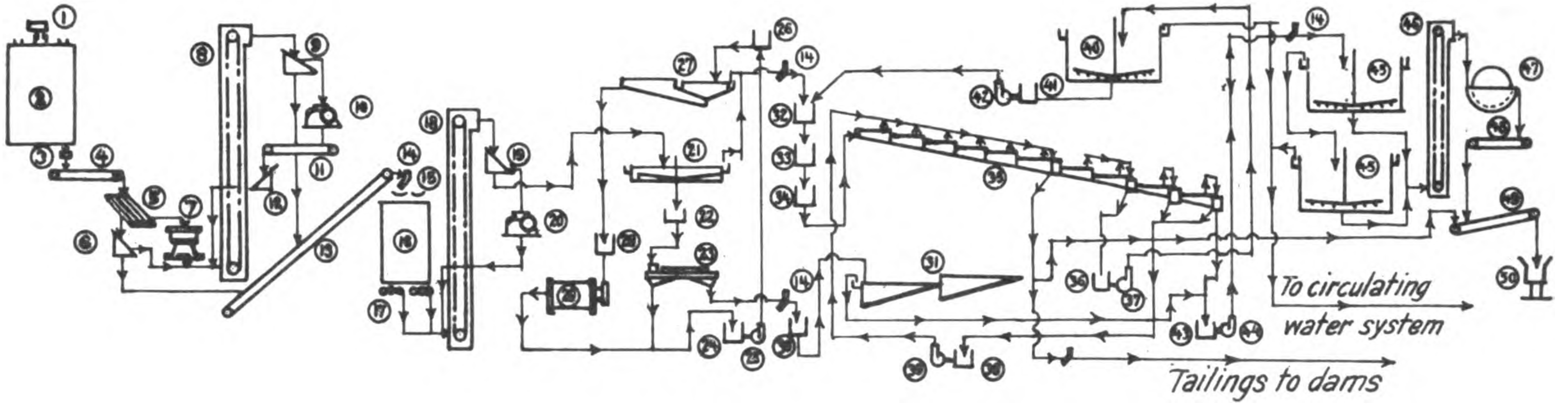
BRIEF HISTORY OF CONCENTRATOR OPERATIONS

Concentrator operations were started in 1911 with No. 8 gyratory crushers and 72 by 20 inch rolls for coarse crushing, 42 by 16 inch rolls with impact screens for fine crushing, Chilean mills for fine grinding, and hydraulic classifiers, tables, and vanners for concentration.

In 1914 flotation concentration was added for the treatment of slime and for the re-treatment of the finer portion of the vanner concentrates.

As originally built, the coarse crushing department consisted of two sections while the balance of the concentrator consisted of five sections. Two additional sections were added to the concentrator in the years 1918 and 1919 making a total of seven sections. These two new sections were equipped with 8 by 6 foot Marcy ball mills for primary grinding and 7 by 10 foot ball mills for secondary grinding. The concentrating equipment of the new sections was similar to that used for the five older sections.

The entire equipment and practically the same flow sheet continued in operation until March, 1923, when all vanners with auxiliary equipment were



Legend of equipment

Mark	No.	Description – I section coarse crushing department
1		55-ton ore cars
2		Coarse ore bins
3		Steel apron feeders
4	1	34-inch belt conveyor
5	1	Grizzly 4'×10'×1 7/8" opening
6	1	Chino screen, 4'6"×6'6"×3/4"×1 1/2"
7	1	No. 8 McCully crusher– 2 1/2" opening
8	1	38-inch bucket elevator
9	1	Chino screen, 4'9"×6'6"×3/4"×1 1/2"
10	1	72 × 20 inch Garfield roll
11	1	Picking conveyor
12	1	Chino screen, 4'6"×6'6"×3/4"× 1 1/2"
13	2	36-inch incline conveyors
14		Automatic electric samplers
15	2	Shuttle conveyors – 28 inch

Mark	No.	Description – I section fine roll crushing fine grinding, and gravity concentration
16	2	Fine ore bins
17	4	Steel apron feeders
18	1	38-inch bucket elevator
19	8	Chino impact screens
20	2	42 x 16 inch Garfield rolls
21	1	20 × 3 1/2 foot Dorr hydroseparator
22	1	12-way table feed distributor
23	12	Deister triple Plat-o concentrating tables
24	1	8-inch Wilfley pump sump
25	2	8-inch Wilfley pumps – 1 operating
26	1	2-way distributor
27	2	Dorr model DSDB 8'×26'8"×15' bowl classifiers
28	1	3-way distributor
29	3	7 × 10 foot Chino ball mills, 19.9 r.p.m.
30	1	2-way distributor
31	2	Dorr model C tandem classifiers vacuum bottom – serving 6 sections

Mark	No.	Description – I section flotation concentration department
32	1	5-way primary flotation feed distributor
33	1	5-way secondary flotation feed distributor
34	1	8-way distributor
35	8	Strings Chino flotation machines
36	1	8-inch Wilfley pump sump
37	4	8-inch Wilfley pumps– 3 operating
38	1	8-inch Wilfley pump sump
39	2	8-inch Wilfley pumps– 1 operating
40		Dorr thickeners for cleaner tails
41	1	8-inch Wilfley pump sump
42	2	8-inch Wilfley pumps– 1 operating
43	1	6-inch Wilfley pump sump
44	2	6-inch Wilfley pumps– 1 operating
45		Dorr thickeners – finished concentrates
46	2	16-inch bucket elevators– 1 operating
47	5	14 × 14 foot vacuum filters– 2 operating
48	1	20-inch belt conveyor
49	1	20-inch belt conveyor– serves all sections
50		55-ton railroad cars

Figure 1.– Flow sheet of treatment for 1925

abandoned and the re-treatment of vanner concentrates was discontinued.

During this same year a reconstruction program was started which included the substitution of Dorr model DSDB, 8-foot by 26-foot 8-inch classifiers with 15-foot bowls for hydraulic classifiers; the replacement of Chilean mills with 7 by 10 foot ball mills, using 3-inch balls, for fine grinding; and the installation of Chino-type pneumatic flotation machines in place of the Janney pyramid-type, mechanical air-flotation machines. These changes were completed in 1925, resulting in a flow sheet as shown in Figure 1.

In 1924 the use of reconstructed coal tar creosote as flotation oil was discontinued, and the reagents sodium ethyl xanthate and pine oil were substituted as selector and frothing reagents, respectively.

The use of magnetic separators was discontinued in October 1926. The ore mined did not require their operation, as the magnetite content became negligible.

In 1927 a change was made in the size of the grinding media in the secondary grinding mills; the 3-inch balls formerly used were replaced with 2-inch balls which resulted in an improvement in grinding operations.

During the same year the use of a high lime circuit in the ball mills for the grading up of concentrates was started. This change increased the percentage of copper in the concentrates approximately 10 units.

The use of tables was discontinued in June, 1927, as the production from that portion of the mine containing the native copper was, and will be, discontinued for a number of years. Table operation is not required on the clean chalcocite ore.

In 1928 and 1929 alterations were made in the coarse crushing department as follows: The No. 8 McCully gyratory crushers were replaced by 7-foot Symons cone crushers followed by Hum-mer screens in place of the Chino impact screens. With the use of Symons cone crushers a very decided increase in reduction ratio was made in this department, the finished product being minus ¼-inch size as compared to minus-¾-inch with the previous equipment.

With the much finer product from the coarse crushing department the use of 42-inch rolls for fine crushing became uneconomical, and each set of two rolls was replaced with one 7 by 10 foot rod mill, using rods of 3-inch diameter. In making this replacement one of the three secondary ball mills of each section was converted to a primary rod mill and the grinding equipment of each section now consists of one primary rod mill and two regrinding ball mills. This change resulted in materially decreasing operating and maintenance costs and in a decided reduction in power consumption without increasing the overall grinding sizes.

In 1929 classification capacity was increased by using one 15-foot bowl classifier for primary classification—that is, handling primary rod-mill discharge—and two 8-foot by 26-foot 8-inch standard drag classifiers for secondary classification, handling ball-mill discharge.

In addition to the above changes, in the latter part of 1928 and the first part of 1929, the pneumatic flotation machines in use were replaced by eight strings of Southwestern-type air-lift matless machines. The use of the matless-type flotation machines resulted in a very decided saving in power, maintenance, and operating costs and also showed an improved recovery, expecially on ores of a high iron content.

COARSE CRUSHING PLANT AT THE MINE

Primary crushing or breaking is done at the mine. The flow sheet of the mine crushing plant with a legend showing number and sizes of machines is given in Figure 2. The present coarse crushing plant consists of two units of gyratory crushers, but a three-unit plant is planned.

The size of the product delivered to the concentrator from this plant is governed by the gyratory crusher and the grizzly with 3-inch openings (item 8 of Fig. 2).

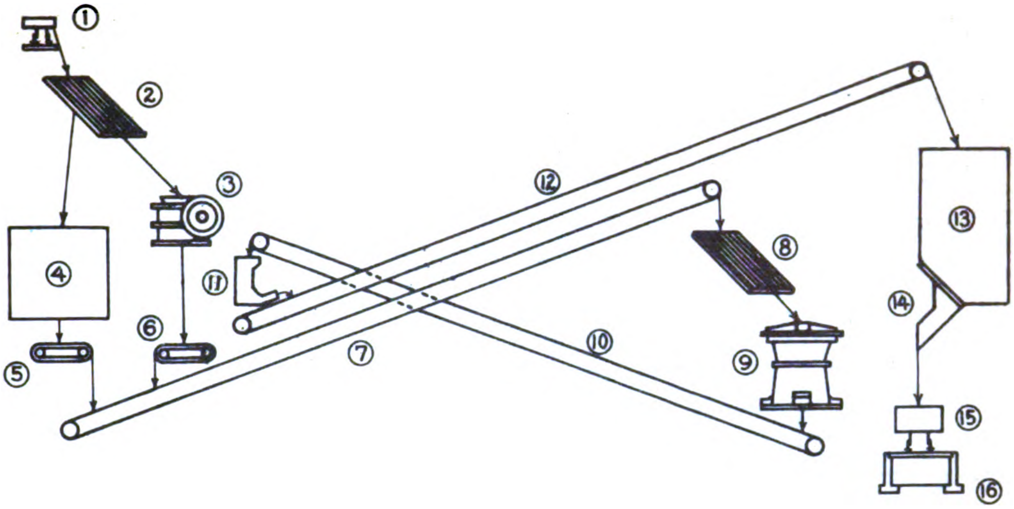
PRESENT METHOD OF CONCENTRATING

The concentrator consists of five departments--namely,--coarse crushing, primary grinding, secondary grinding, flotation, and dewatering or filtering.

Coarse Crushing at the Concentrator

The coarse crushing department of the concentrator consists of three units, each of which is equipped with one 34-inch feed conveyor, one 7-foot Symons cone crusher, six Hum-mer screens, one 38-inch elevator, and one set of 72 by 20 inch Garfield rolls. The three units of this department are served by two 36-inch incline conveyors and two 28-inch shuttle conveyors for distribution of ore into the fine ore bins.

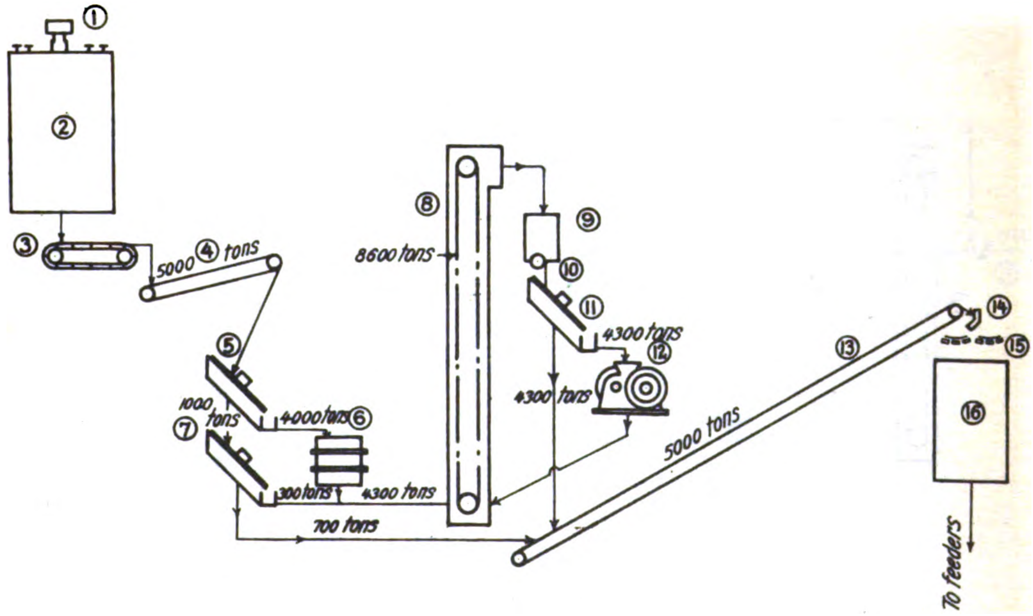
The flow sheet of one unit of the coarse crushing department with accessory equipment serving the three units is shown in Figure 3. Ore is delivered from the coarse ore bins at minus-4-inch size to one 4 by 5 foot Hum-mer screen by steel apron feeders and one 34-inch belt conveyor. The Hum-mer screen has openings ¾ by 1½ inch in size and is equipped with 0.250-inch wire and a V-40 vibrator. The oversize product feeds a 7-foot Symons cone crusher set at ½-inch size and operating at the rate of 230 gyrations per minute. The undersize product of the Hum-mer screen goes to one 4 by 7 foot Hum-mer screen equipped with two V-40 vibrators. This screen has ¼ by ¾ inch size openings, the wire size being 0.063-inch diameter. The oversize product of this screen joins the crushed product from the Symons cone crusher and drops into the boot of a 38-inch bucket elevator. This elevator is equipped with a double row of 18 by 10½ by 8 inch buckets spaced 22 inches apart and discharges into a surge bin from which the ore is drawn by means of drum type feeders to four 4 by 5 foot Hum-mer screens equipped with V-40 vibrators. The wire size of these screens is 0.063-inch diameter and the openings are ¼ by ¾ inches in size. The oversize products of these screens feed one set of 72 by 20 inch Garfield rolls running at a speed of 110 revolutions per minute. The rolls operate in closed circuit with the 38-inch



Legend of equipment - primary crushing department

Mark	No.		Mark	No.	
1		20 or 30 cu. yd. side-dump cars	9	2	No. 8 gyratory crushers
2	1	Grizzly - 8-inch opening	10	1	60-inch belt conveyor
3	1	84 × 66 inch jaw crusher	11	1	2-way splitter
4	1	Undersize bin	12	2	42-inch belt conveyors
5	2	Undersize bin feeders	13	1	Storage bin
6	2	Crushed product feeders	14		Pneumatic operated gates
7	2	42-inch belt conveyors	15		55-ton ore cars to crushers
8	2	Grizzlies - 3-inch opening	16	1	Railroad track scale

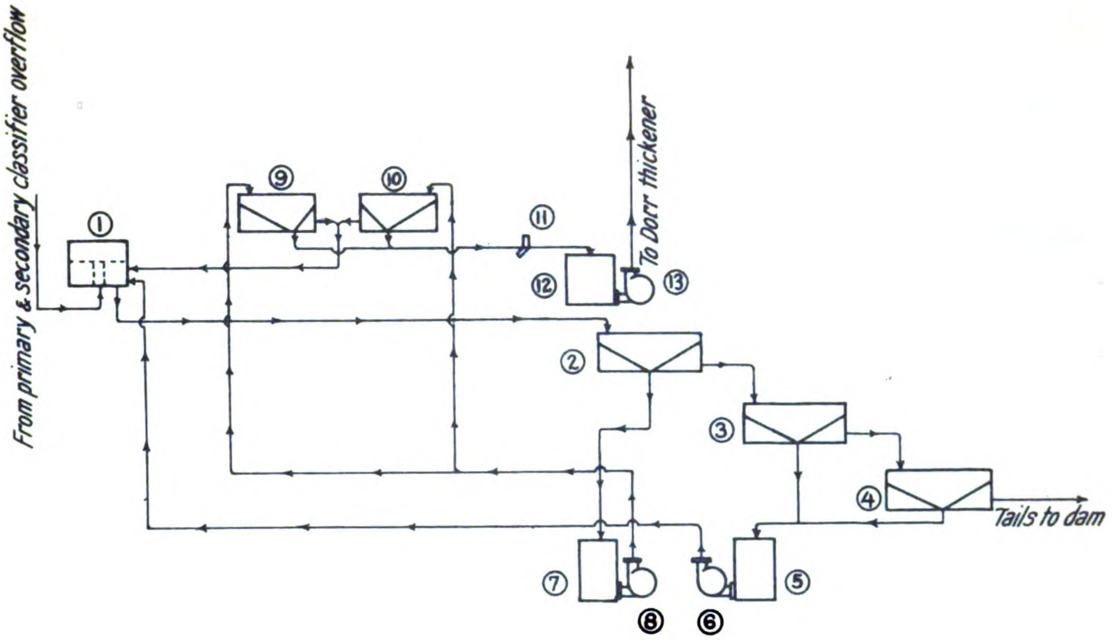
Figure 2.- Flow sheet of coarse crushing plant at mine



Legend of equipment - coarse crushing department

Mark	No.		Mark	No.		Mark	No.	
1		55-ton ore cars	7	1	4 × 7 foot hummer screen	13	2	36-inch incline conveyors for 3 units
2		Coarse ore bins- ore, -4 inch	8	1	38-inch bucket elevator	14	2	Automatic electrical samplers
3	19	Steel apron feeders	9	1	Surge bin	15	2	Shuttle conveyors - 28 inch
4	1	34-inch belt conveyors	10	4	Pulley-type feeders	16		Fine ore bins - capacity, 12,000 tons
5	1	4 × 5 foot Hummer screen	11	4	4 × 5 foot Hummer screens			
6	1	7-foot Symons cone crusher	12	1	72 3 20 inch Garfield roll			

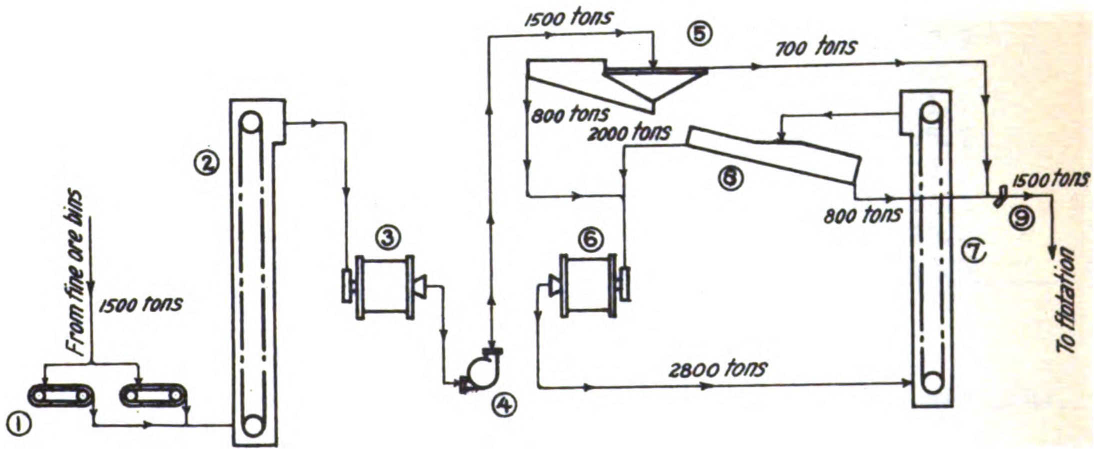
Figure 3.- Flow sheet of one unit of concentrator coarse-crushing department



Legend of equipment - primary and secondary grinding

Mark	No.		Mark	No.		Mark	No.	
1	4	Steel apron feeders	4	2	6-inch Wilfley pumps- 1 operating	7	2	20-inch bucket elevators
2	1	20-inch bucket elevator	5	1	8'×26'8"×15' Dorr bowl classifier	8	2	8'×26'8" Dorr drag classifiers
3	1	7 × 10 foot rod mill	6	2	7 × 10 foot ball mills	9	1	Automatic electrical sampler

Figure 4.- Flow sheet of one section of primary and secondary grinding units



Legend of equipment - flotation department

Mark	No.		Mark	No.	
1	2	4-way flotation distributors	8	8	6-inch Wilfley pumps
2	8	Matless flotation rougher cells	9	2	Matless flotation cleaner cells
3	8	Matless flotation rougher cells	10	2	Matless flotation cleaner cells
4	8	Matless flotation rougher cells	11		Automatic electric samplers
5		8-inch Wilfley pump sump	12	1	Finished concentrates sump
6	8	8-inch Wilfley pumps - 4 operating	13	2	6-inch Wilfley pumps- 1 operating
7		6-inch Wilfley pump sump			

Figure 5.- Flow sheet of flotation department

elevator and Hum-mer screens. An inclined 36-inch belt conveyor delivers the finished product of this circuit, together with the undersize product of the second Hum-mer screen, to the fine ore bins where the ore is distributed by two 28-inch shuttle conveyors.

Table 1 gives screen analyses of the Symons crusher and final crushing plant products.

Table 1. - Screen analyses of coarse crushing plant products

Screen size	Symons crusher product		Final coarse crushing plant product	
	Weight, per cent	Cumulative per cent	Weight, per cent	Cumulative per cent
On 0.742 inch....	3.1	3.1	—	—
On 0.525 inch....	15.7	18.8	—	—
On 0.371 inch....	21.7	40.5	—	—
On 3 mesh........	19.1	59.6	—	—
On 4 mesh........	14.0	73.6	5.5	5.5
On 6 mesh........	6.0	79.6	13.5	19.0
On 8 mesh........	3.1	82.7	12.4	31.4
On 10 mesh.......	2.1	84.8	10.5	41.9
On 14 mesh.......	1.6	86.4	8.4	50.3
On 20 mesh.......	1.0	87.4	6.7	57.0
On 28 mesh.......	1.0	88.4	5.9	62.9
On 35 mesh.......	0.7	89.1	4.9	67.8
On 48 mesh.......	1.1	90.2	3.9	71.7
On 65 mesh.......	0.9	91.1	3.5	75.2
On 100 mesh......	1.0	92.1	4.1	79.3
On 150 mesh......	1.1	93.2	2.8	82.1
On 200 mesh......	1.3	94.5	2.9	85.0
Minus-200 mesh...	5.5	5.5	15.0	15.0

Primary and Secondary Grinding

The primary and secondary grinding departments include nine sections, each with a normal capacity of 1,500 tons of ore per day.

Figure 4 is the flow sheet of one unit of primary and secondary grinding departments which gives approximate ore tonnages and a legend showing the number and sizes of machines.

For sections 1 to 4, inclusive, the ore is drawn from the bottom of the fine ore bins by means of steel apron feeders, two feeders being installed for each bin. The apron feeders discharge into a 20-inch elevator equipped with a single row of 18 by 8 by 10½ inch buckets spaced 34 inches apart. This elevator feeds one 7 by 10 foot primary rod mill. The rod mill discharge product is pumped to a model DSDB, 8-foot by 26-foot 8-inch by 15-foot Dorr bowl classifier, by one 6-inch Wilfley sand pump. The rakes of the classifier operate at 29 strokes per minute and the bowls are equipped with variable speed motors so that, depending upon the character of the ore, the speed of the bowl rakes can be controlled between 1.5 and 5.0 revolutions per minute. The overflow product is flotation feed and the sand product is split equally to two 7 by 10 foot secondary ball mills. The discharge product of each ball mill is elevated by a 20-inch elevator equipped with a single row of 18 by 8 by 10½-inch buckets spaced 17 inches apart to one 8-foot by 26-foot 8-inch standard Dorr circulating classifier with rakes operating at 20 strokes per minute. This classifier operates in closed circuit with the secondary ball mill. The classifier overflow product is flotation feed.

The flow of the ore for sections 5 to 9, inclusive, is the same as described for sections 1 to 4, inclusive, with the exception that the rod mill is fed by a 28-inch belt conveyor instead of a bucket elevator.

Tables 2 and 3 give tabulated grinding mill data for the primary rod mills and secondary ball mills respectively.

Table 4 gives screen analyses of primary and secondary grinding feeds and products.

Table 2. - Operating data for primary rod mills

Number of mills per section......................	1
Size of mills:	
Diameter, feet........................	7
Length, feet..........................	10
Speed of mills, r. p. m.........................	19.9
Size of rods:	
Diameter, inches......................	3
Length, inches........................	110½
Rod data from manufacturer, kind...............	Heat treated and machine straighte
Carbon content of rods, per cent................	0.90 to 1.05
Rod load, pounds................................	42,000
Rod consumption, pounds per ton of ore milled.	0.40
Kind of liners:	
Side..................................	White iron
End...................................	Manganese steel
Lifting bars:	
Kind..................................	Manganese steel
Number to the circle..................	20
Weight of liners complete, pounds..............	38,650
Approximate life of liners, days...............	450
Type of drive..................................	Direct connected to 175-horsepower synchronous motor. Helical gears, enclosed magnetic clutch.
Power required, kilowatts.......................	115
Average ore handled per mill per 24 hours, tons	1,500
Density of feed, per cent of solids............	65

Table 3. - Operating data for secondary ball mills

Number of mills per section	2
Size of mills:	
Diameter, feet	7
Length, feet	10
Speed of mills, r. p. m.	19.9
Balls:	
Kind	White iron
Diameter, inches	2
Load, pounds	36,000
Consumption, pounds per ton milled.	1.46
Side liners:	
Kind	Rails
Length, inches	3½
Life, days	672
End liners:	
Kind	White iron
Life, days	123
Weight of liners, complete, pounds	30,218
Lifting bars:	
Kind	Rails
Length, inches	6
Number to circle	10
Type of drive	Direct connected to 175-horsepower synchronous motor, Falk helical gears, enclosed magnetic clutch.
Power required, kilowatts	121
Average weight of new feed handled per mill per day, tons	400
Density of feed, per cent of solids	70

Table 4. - Screen analyses of primary and secondary grinding mill feeds and products

	Primary rod mills						Secondary ball mills			
	Feed		Primary classifiers				Feed		Secondary classifier overflow	
			Feed		Overflow					
	Weight, per cent	Cumulative per cent	Weight, per cent	Cumulative per cent	Weight per cent	Cumulative per cent	Weight, per cent	Cumulative per cent	Weight, per cent	Cumulative per cent
On 4.......	5.5	5.5	--	--	--	--	--	--	--	--
On 6.......	13.5	19.0	--	--	--	--	--	--	--	--
On 8.......	12.4	31.4	0.4	0.4	--	--	0.4	0.4	--	--
On 10......	10.5	41.9	1.0	1.4	--	--	0.8	1.2	--	--
On 14......	8.4	50.3	3.2	4.6	--	--	5.4	6.6	--	--
On 20......	6.7	57.0	4.4	9.0	--	--	10.8	17.4	--	--
On 28......	5.9	62.9	10.4	19.4	--	--	17.0	34.4	--	--
On 35......	4.9	67.8	9.4	28.8	--	--	20.2	54.6	--	--
On 48......	3.9	71.7	10.2	39.0	2.6	2.6	15.6	70.2	--	--
On 65......	3.5	75.2	7.6	46.6	6.0	8.6	11.8	82.0	2.9	2.9
On 100.....	4.1	79.3	9.8	56.4	11.3	19.9	8.0	90.0	11.9	14.8
On 150.....	2.8	82.1	5.8	62.2	9.4	29.3	3.6	93.6	12.9	27.7
On 200.....	2.9	85.0	4.6	66.8	10.4	39.7	1.6	95.2	15.1	42.8
Through 200	15.0	15.0	33.2	33.2	60.3	60.3	4.8	4.8	57.2	57.2

Flotation

Figure 5 shows the flow sheet of the flotation department. The flotation plant is composed of eight rows of Southwestern air-lift matless rougher flotation machines, each row having three cells, making a total of 24 rougher cells. Each rougher flotation cell is 27 feet long by 6 feet 6 inches wide by 3 feet deep. Each two rows of rougher machines are served by one cleaner cell, 18 feet long by 6 feet 6 inches wide by 3 feet 6 inches deep, with the exception of two rows which are used for experimental purposes. Each of the latter rows is served by one cleaner cell, one-half the length of the regular cleaner cell. As shown in Figure 5, the combined classifier overflow products of all grinding sections are delivered to two flotation feed distributors. Each of these distributors serves one-half of the flotation plant and each splits its feed equally to four rows of flotation machines. A rougher concentrate is produced by the first cell and is pumped by means of a 6-inch Wilfley sand pump to a cleaner cell for finishing. The second and third rougher cells of each row make middlings products which are pumped to the distributors feeding the first rougher cell by 8-inch Wilfley sand pumps where they join the tailings of the cleaner machines, the total product being re-treated with new flotation feed.

Air is furnished to the flotation cells by Roots blowers at the rate of 4.45 cubic feet per ton of ore concentrated, at a pressure of 2 pounds per square inch at the blower or $1\frac{1}{2}$ pounds at the flotation cells. The air headers are 12 inches in diameter and the drop pipes are of 1-inch diameter on the rougher cells and $\frac{3}{4}$-inch diameter on the cleaner cells. The power consumption for flotation amounts to 1.4 kilowatt-hours per ton of ore treated.

The flotation reagents used at present consist of lime, raconite, and steam distilled pine oil.

The lime is added to the rod and ball mill feeds in the form of milk of lime which is prepared as follows: Burnt lime is received in railroad cars and averages approximately 75 per cent of available CaO. Sufficient water for the complete hydration of approximately 75,000 pounds of lime is run into a large concrete bin to which the lime is added with a Gantry crane. After slacking is complete, the slacked lime is washed into an adjoining concrete bin through a gate at the bottom; the milk of lime is then washed, by means of a fire hose, through a 5-mesh screen with 0.128 inch openings and 0.072 inch wire, to a 6-inch Wilfley pump which discharges into a 75 by 20-foot Dorr tank for storage. The discharge from this storage tank is pumped to a distributor where the required lime for each section is taken off and the excess returned to the tank. Sufficient lime is used to maintain an approximate alkalinity equivalent to 11 cubic centimeters of tenth normal hydrochloric acid per 100 cubic centimeters of tailings water. This amounts to approximately 0.60 pounds of free CaO per ton of tailings water.

The raconite mixture is manufactured at this plant, the method of manufacture being recently described by W. I. Garms.[3] This reagent is diluted to 10 per cent strength for mill use and is again diluted by a large addition of water just before the reagent joins the ore pulp. The object of diluting is to distribute the raconite more readily through the pulp. This reagent is added to the primary and secondary classifier overflow products of each section, in the

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3 - Garms, W. I., Concentrator Methods and Costs at the Hayden Plant of the Nevada Consolidated Copper Co., Hayden, Ariz., U. S. Bureau of Mines Information Circular 6241, Feb., 1930, 25 pp.

ratio of 50 per cent to the primary product and 50 per cent to the secondary product.

The pine oil, Yarmor steam distilled, is added to the pump sumps receiving the middlings products of the rougher cells. The addition at these points is made to obtain greater emulsification by means of the middlings pumps before the reagent enters the flotation cells.

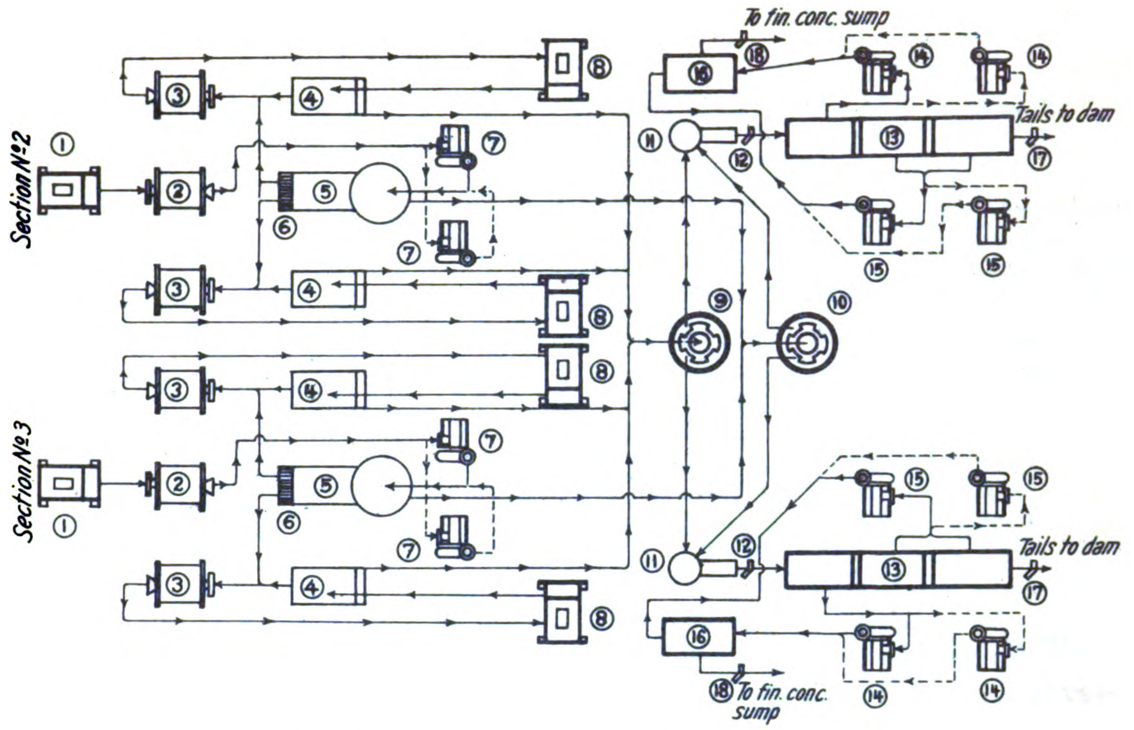
In the year 1929 an experimental unit was installed on sections 2 and 3 of the fine grinding department, followed by two rows of flotation machines. The flow sheet of this experimental unit is shown with legend in Figure 6. It will be noted in Figure 6 that the primary classifier overflow products from both sections 2 and 3 are combined and the total is split in two equal parts; also the secondary overflow products from the two sections are combined and split equally.

The half portions of the primary and secondary overflow products combine and constitute the feed to each of the flotation rows. The reason for combining and splitting the primary and secondary overflow products is that there exists at times a wide difference in ore on the different fine grinding sections, and the arrangement here shown eliminates any possibility of different feeds to the flotation units.

Table 5 gives screen analyses and distributions of copper in flotation heads, concentrates, and tailings products.

Table 5. - Screen analyses and distributions of copper in flotation products

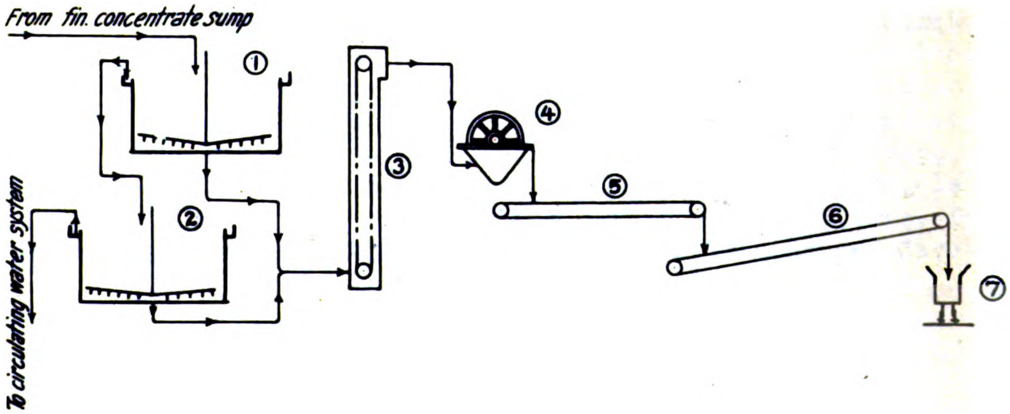
	Flotation heads						
Screen size, mesh	Weight		Assay, per cent copper	Weight		Total Copper	
	Per cent	Cumulative per cent		Units of copper	Cumulative units of copper	Per cent	Cumulative per cent
On 48	0.9	0.9	0.36	0.003	0.003	0.2	0.2
On 65	5.1	6.0	0.35	0.018	0.021	1.4	1.6
On 100	12.9	18.9	0.38	0.049	0.070	3.7	5.3
On 150	11.4	30.3	0.66	0.075	0.145	5.7	11.0
On 200	10.9	41.2	1.07	0.117	0.262	8.8	19.8
Through 200	58.8	58.8	1.80	1.058	1.058	80.2	80.2
Composite ..	100.0	100.0	1.32	1.320	1.320	100.0	100.0



Legend of equipment - experimental test unit sections Nos. 2 and 3

Mark	No.		Mark	No.		Mark	No.	
1	2	20-inch bucket elevator-primary	7	4	6-inch Wilfley pumps- 2 operating	13	2	3 wide matless flotation rougher cells
2	2	7 × 10 foot rod mills	8	4	20-inch bucket elevator- secondary	14	4	4-inch Wilfley pumps- 2 operating
3	4	7 × 10 foot ball mill	9	1	Secondary classifier overflow distributor	15	4	6-inch Wilfley pumps- 2 operating
4	4	8'×26'8" Dorr drag classifiers	10	1	Primary classifier overflow distributer	16	2	Wide matless flotation cleaner cells
5	2	8'×26'8"×15'Dorr drag classifiers	11	2	Junction box primary and secondary classifier overflow	17	2	Automatic electrical flotation tail sampler
6	2	Jones riffler	12	2	Automatic electrical flotation head sampler	18	2	Automatic electrical finished concentrates sampler

Figure 6.- Flow sheet of experimental unit



Legend of equipment - concentrates dewatering department

Mark	No.		Mark	No.	
1		Dorr thickener - 48 × 20 feet	5	1	20-inch belt conveyor
2		Dorr thickener - 75 × 20 feet	6	1	20-inch belt conveyor
3	2	16-inch bucket elevators - 1 operating	7		55-ton railroad cars
4	5	14 × 14 foot vacuum filters			

Figure 7.- Flow sheet for dewatering flotation concentrates

Table 5 - Screen analyses and distributions of copper in flotation products (Continued)

Flotation concentrates

Screen size, mesh	Weight		Assay, Per cent Copper	Weight		Total copper	
	Per cent	Cumulative per cent		Units of copper	Cumulative units of copper	Per cent	Cumulative per cent
On 65......	1.2	1.2	8.41	0.101	0.101	0.4	0.4
On 100.....	4.5	5.7	11.87	0.534	0.635	1.9	2.3
On 150.....	8.2	13.9	15.61	1.280	1.915	4.7	7.0
On 200.....	13.1	27.0	18.26	2.392	4.307	8.6	15.6
Through 200	73.0	73.0	31.83	23.236	23.236	84.4	84.4
Composite..	100.0	100.0	27.54	27.543	27.543	100.0	100.0

Flotation tailings

Screen size, mesh	Weight		Assay, Per cent copper	Weight		Total copper	
	Per cent	Cumulative per cent		Units of copper	Cumulative units of copper	Per cent	Cumulative per cent
On 48......	0.9	0.9	0.37	0.003	0.003	1.4	1.4
On 65......	5.3	6.2	0.27	0.015	0.018	6.7	8.1
On 100.....	13.3	19.5	0.22	0.029	0.047	13.2	21.3
On 150.....	11.5	31.0	0.21	0.024	0.071	10.8	32.1
On 200.....	10.8	41.8	0.20	0.022	0.093	10.0	42.1
Through 200	58.2	58.2	0.22	0.128	0.128	57.9	57.9
Composite..	100.0	100.0	0.22	0.221	0.221	100.0	100.0

DEWATERING OF FLOTATION CONCENTRATES

Figure 7 gives the flow sheet for dewatering flotation concentrates. Flotation concentrates of the entire mill are delivered to one 48 by 20 foot Dorr thickener by one 6-inch Wilfley pump. The overflow water of this thickener flows to one 75 by 20 foot Dorr thickener, the clear overflow water from this second thickener being returned to the mill circuit. The concentrates pulp, thickened from 18.5 per cent of solids to 70.0 per cent of solids, is fed to 14 by 14 foot Oliver filters. The filter plant contains five filters, four of the Oliver type and one Dorrco filter. The filter cake is conveyed directly to railroad cars.

The following tabulation gives filter plant data:

Kind of filter cloth used..........................	No. 26 filter fabric 17-ounce duck.
Kind of wire used for wrapping...............	No. 9 hard drawn galvanized filter wire.
Spacing of wire, inches..	2¼.
Life of filter cloth, days..	100.
Amount of vacuum used, inches of mercury..................................	20.5.
Weight of concentrates filtered per square foot of filter surface, tons.....	14.45.

DISPOSAL OF TAILINGS AND WATER RECOVERY FROM TAILINGS PULP

The final tailings product, containing 21.7 per cent of solids, is conveyed by gravity through a 30-inch diameter, continuous, wooden-stave pipe line a distance of 6,590 feet to the settling ponds, the slope of the pipe line being 4.725 feet per 1,000.

Figure 8 shows a plan of the tailings disposal and water reclaiming system.

The 30-inch line discharges into a cylindrical concrete box which feeds the distributing lines. Distribution of tailings pulp around the settling pond is effected by means of 20-inch diameter wooden-stave pipe lines or launders. All pipe lines are set level with sufficient head on the inlet to force the pulp to the desired point. Where launders are employed, they are set with a slope of 6 feet per 1,000, except on curves, where the slope is increased to approximately 8 feet per 1,000.

The settling ponds are rectangular or square in shape, and the sides are from one-quarter to one-half mile in length. Owing to the comparatively flat nature of the country, borders must be maintained on all sides. As the tailings area is filled the distributing lines are raised 16 feet and moved inward 32 feet, a slope of approximately two to one being maintained on the borders.

Distribution of tailings around the outer edge of the pond is accomplished by means of holes spaced 10 feet apart in the bottom of the distributing line, the discharge from each hole being conveyed to the extreme edge of the border by a 4 by 4 inch launder 16 feet long. The water and very fine slime drain to the center of the pond, leaving the coarser sands deposited on the dike clear of the trestle carrying the distributing lines. The height of the crest of the dike is approximately 2 feet above the water in the pond and is maintained by a Martin ditcher drawn by a caterpillar tractor.

The settling pond now in service has a total area of 90 acres with an exposed water surface of 8 acres. Of the total water sent to the pond about 60 per cent is recovered, the loss being due to water held with the tailings, to evaporation, and to a small amount of seepage. Clear water is reclaimed through one or more dewaterers located toward the central part of the pond and connected to a gathering pipe line on the natural ground under the deposited tailings. The dewaterers are constructed of 4 by 6 inch timbers laid flat, have an inside dimension of 4 feet, and are maintained at a sufficient height to give a clear overflow. The gathering line discharges by gravity into the main storage lake.

A 36-inch diameter reinforced tile line is located in the natural ground under the main storage lake, extending through the center and for the full width of the lake. A series of dewaterers, of the same type as those in the settling pond, are directly connected with this line. The height of the dewaters regulates the volume of water drawn off. The recovered water flows through this line to a vertical shaft and from there is pumped into a canal.

The pumping equipment at this station consists of two 3,000 gallons per minute Worthington Axiflo pumps and one 8,000 gallon per minute Kimball pump. The operation of these pumps is governed by the elevation of the water in the lake. During the greater portion of the year the elevation is sufficient to overflow the required volume of water by gravity to the canal.

The canal discharges into an artificial lake, situated east of the mill, where a permanent pump station is located. This station is equipped with four 2-stage Cameron centrifugal pumps each with a capacity of 3,000 gallons per minute. The reclaimed water, together with any flood water, is pumped to the mill reservoir, which has a capacity of 15,000,000 gallons, through two 24-inch diameter, continuous, wooden-stave pipe lines for a distance of 4,768 feet and under a static head of 180 feet.

SAMPLING

All samples are taken automatically with electric samplers which are governed by a master timer regulating their operation to one cut every eight minutes.

The general mill heads sample is taken at the discharge of the inclines conveyors, just before delivery of the ore to the fine ore bins, and is removed to the sample room each morning at 7 o'clock. The total weight of this sample amounts to 1,800 pounds, and riffling reduces this weight to 25 pounds. This sample is used for both moisture and copper determinations. Due to the loss of moisture, which takes place in this sample before riffling and removal to the sampling room, a factor is added to the moisture analyses to compensate for this loss. The heads sample is cumulative for the 24-hour period; shift samples are not segregated.

All flotation tailings products are combined in one common launder from which the general mill tailings sample is obtained. The total dry weight of the sample averages 24 pounds, and this weight is reduced by riffle to assay size.

The finished flotation concentrates pulp is pumped from the plant to one 48 by 20 foot Dorr thickener and is sampled just before entering this thickener tank. The weight of this sample after drying is approximately 10 pounds.

In addition to the sampling described, samples are taken of the tailings products of the individual flotation units. This is done as a precaution in case the general mill tailings sample is spoiled, or the general mill tailings sampler be down for repairs.

Auger samples are taken of each carload of concentrates for purpose of checking the general flotation concentrates samples. The sampling of each carload of concentrates represents a composite of 48 auger holes distributed regularly over the area of the car. The average of the assays of auger samples checks the results obtained from the general flotation concentrate's sample.

METALLURGICAL CALCULATIONS

The ore is weighed on railroad scales at the mine and is delivered at the concentrator by the Atchison, Topeka & Santa Fe Railway.

The weight of ore milled each day is determined by estimating the amount of ore on hand, subtracting the amount on hand the previous morning and adding to this the actual weight of the ore received for the day. The weight of ore milled is reported in dry tons, being corrected for moisture, according to the moisture determination made on the heads sample.

Having determined the dry tons of ore milled for the day, the weight of copper in the heads is determined from this figure and the assay of the heads sample. The ratio of concentration is then determined from the formula, $\frac{C - T}{H - T}$, where H, C, and T represent the copper contents of the heads, concentrates and tailings, respectively.

The dry tons of ore milled divided by the ratio of concentration gives the weight of concentrates produced, in dry tons. The weight of heads minus the weight of concentrates equals the weight of tailings. The pounds of copper in the tailings is computed from the weight of tailings and the copper assay of the tailings sample. The pounds of copper in the tailings deducted from the pounds of copper in the heads gives the indicated extraction of copper, in pounds, The indicated copper extraction, in per cent, is obtained from the indicated pounds of copper recovered and the pounds of copper contained in the heads.

WATER SUPPLY

The initial water is obtained from five different sources, namely — Apache Tejo, Bolton Ranch, "B" Ranch, Whiskey Creek, and Cameron Creek pump stations.

Apache Tejo Stations:--The Apache Tejo station from which the main source of supply is obtained is located 4 miles south of the concentrator.

The water is obtained from three wells having individual depths of 777 feet, 881 feet, and 2,445 feet. The water level at the present time is 146 feet below the surface. The water is raised by air lifts and delivered to a concrete reservoir from which it is pumped by two Aldrich quintuplex plunger pumps through a 20-inch diameter steel pipe line with a length of approximately 20,000 feet under 400 feet static head, to a 223,000-gallon initial water supply tank.

The air lifts are served by three Ingersoll-Rand, type XB-2, 17 by 10 by 14 inch compressors.

The maximum capacity of this station is approximately 2,600 gallons per minute. The amount pumped, however, is dependent upon requirements which normally are 980 gallons per minute.

The water from this source supplies domestic and power plant requirements. The surplus is used for milling purposes.

Bolton Ranch Station:--This station is located approximately 2½ miles southeast of the concentrator and at present has a normal output of 690 gallons per minute. The water is pumped from a distance of 210 feet below the surface by a deep well pump through 4,500 feet of 14-inch diameter steel pipe under a static head of 270 feet. The pipe line discharges this water into the canal where it joins the overflow water from the main storage lake.

"B" Ranch Station:--The "B" Ranch station is located one-half mile northeast of the concentrator and has a normal output of 514 gallons per minute. The water is obtained by means of a drainage tunnel located on bed rock across Whitewater Creek and flows by gravity to the suction of a 10-inch diameter by 12-inch stroke Aldrich vertical triplex pump. This water is pumped to the mill reservoir a distance of 3,100 feet through an 8-inch diameter steel pipe line under a static head of approximately 180 feet.

Whiskey Creek:--The Whiskey Creek station is located about 5 miles west of the concentrator and has a normal output of 171 gallons per minute. The water is obtained by means of a drainage tunnel along the bed of the creek and is pumped a total distance of 9,300 feet to the Cameron Creek station where it is relayed to the mill reservoir. The station is equipped with a triplex pump of the same size as that at the "B" Ranch station, and this pump operates against a total head of 290 feet.

Cameron Creek:--Cameron Creek station is located 3 miles west of the concentrator and has a normal output of 190 gallons per minute. This station is equipped with an Aldrich triplex pump of the same size as those at the "B" Ranch and Whiskey Creek stations. The water is pumped through a 14-inch diameter steel pipe line directly to the mill reservoir. This line is about 17,000 feet long and the combined static and friction head is approximately 290 feet. The source of the water supply at this station is drainage into Cameron Creek from the surrounding country.

In addition to the water stations enumerated, a well is located in the main storage lake which furnished 245 gallons of water per minute from an underground flow not connected with the lake.

The impurities in the water have no marked effect on ore treatment. Due to the high lime content maintained in the milling circuit, all detrimental salts are precipitated when new water is mixed with the strongly alkaline reclaimed water.

The total water for milling purposes amounts to 850 gallons per ton of ore treated, of which 40 per cent is initial water and 60 per cent reclaimed water.

The total power consumption for mill water amounts to 2.352 kilowatt-hours per ton of ore milled, distributed as follows:

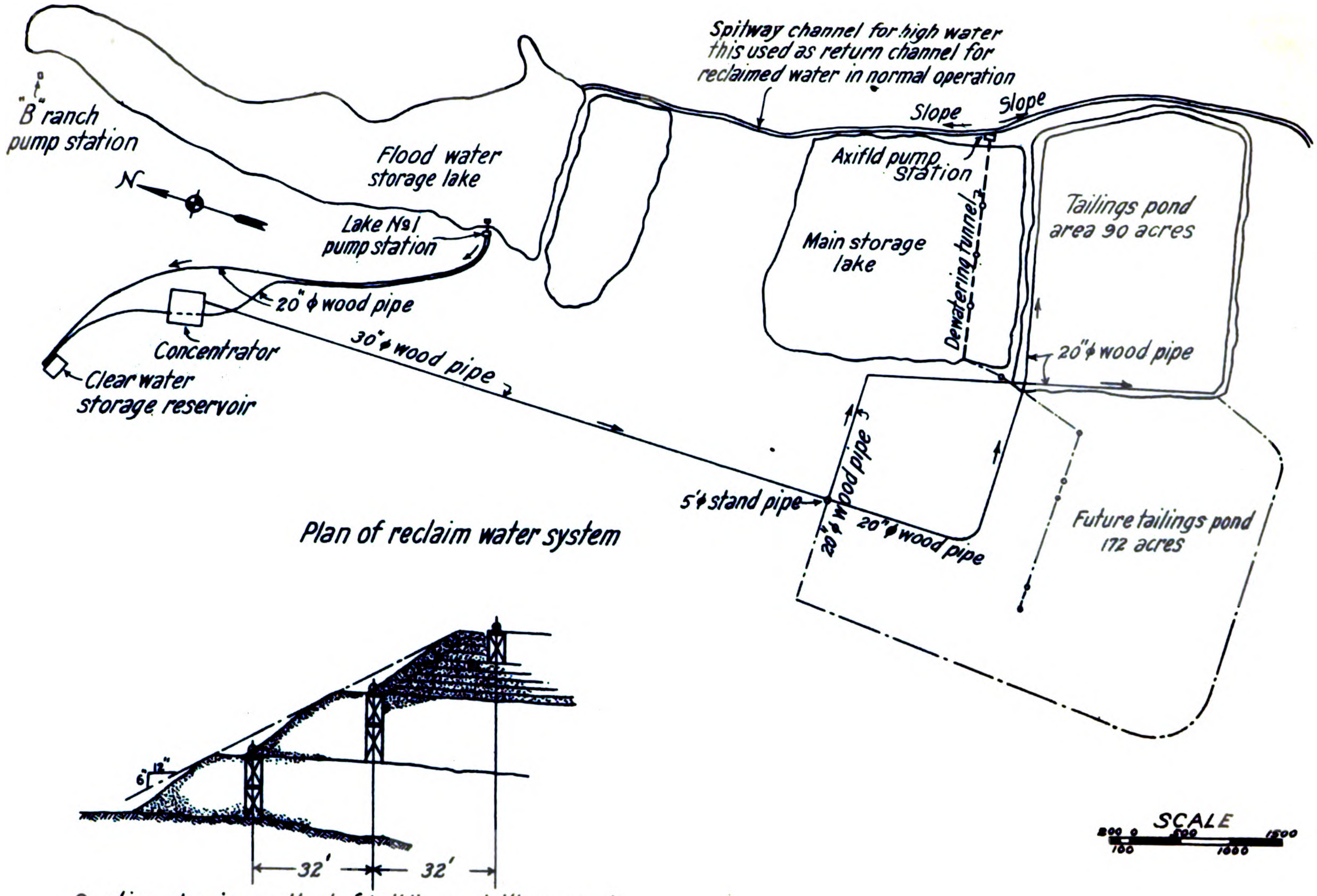
Initial water	1.550 kw.h. per ton
Reclaimed water	0.736 kw.h. per ton
Circulating water	0.066 kw.h. per ton
Total	2.352 kw.h. per ton

DISTRIBUTION OF POWER

Table 6 shows the distribution of electric power consumed.

Table 6. - Distribution of power

	kw.h. per ton of ore milled	Per cent of total power
Coarse crushing:		
Crushers	0.349	
Conveyors	.362	
Rolls	.764	
Elevators	.290	
Other machinery	.045	
Total	1.810	13.9
Primary grinding:		
Elevators	0.224	
Rod mills	1.840	
Pumps	.248	
Other machinery	.163	
Total	2.475	19.0
Secondary grinding:		
Ball mills	4.050	
Elevators	.352	
Classifiers	.160	
Other machinery	.143	
Total	4.705	36.1
Flotation:		
Blowers	0.888	
Pumps	.401	
Other machinery	.111	
Total	1.400	10.8
Dewatering:		
Elevators	0.026	
Filters	.015	
Pumps (Wilfley)	.087	
Pumps (vacuum)	.102	
Conveyors	.017	
Other machinery	.033	
Total	.280	2.2
Water supply	2.352	18.0
Grand total	13.022	100.0



Plan of reclaim water system

Section showing method of building up tailings pond

Figure 8.- Plan of tailings-disposal and water-reclaiming system